

11/27/00

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PTO/SB/05 (2/98)  
OMB 0651-0032

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+

Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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# UTILITY PATENT APPLICATION TRANSMITTAL

Attorney Docket No.	4015-784
First Inventor or Application Identifier	Essam Sourour
Title	MULTIPATH INTERFERENCE REDUCTION FOR A CDM SYSTEM
Express Mail Label No.	EL659733665US

(Only for new nonprovisional applications under 37 CFR § 1.53(b))

## APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents  
Box Patent Application  
Washington, DC 20231

- ☒ \*Fee Transmittal Form (e.g., PTO/SB/17)  
(Submit an original and a duplicate for fee processing)
- ☒ Specification [Total Pages 34]  
(preferred arrangement set forth below)
  - Descriptive title to the Invention
  - Cross References to Related Applications
  - Statement Regarding Fed sponsored R & D
  - Reference to Microfiche Appendix
  - Background of the Invention
  - Brief Summary of the Invention
  - Brief Description of the Drawings (if filed)
  - Detailed Description
  - Claim(s)
  - Abstract of the Disclosure
- ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets 10]
- ☒ Oath or Declaration [Total Pages 3]
  - ☒ Newly executed (original or copy)
  - ☐ Copy from a prior application (37 C.F.R. § 1.63(d))  
(for continuation/divisional with Box 17 completed)  
[Note Box 5 below]
    - ☐ DELETION OF INVENTOR(S)  
Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).
- ☐ Incorporation By Reference (useable if Box 4b is checked)  
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

- ☐ Microfiche Computer Program (Appendix)
- Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)
  - ☐ Computer Readable Copy
  - ☐ Paper Copy (identical to computer copy)
  - ☐ Statement verifying identity of above copies

## ACCOMPANYING APPLICATION PARTS

- ☒ Assignment Papers (cover sheet & document(s))
- ☐ 37 C.F.R. § 3.73(b) Statement ☒ Power of Attorney (when there is an assignee)
- ☐ English Translation Document (if applicable)
- ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
- ☐ Preliminary Amendment
- ☒ Return Receipt Postcard (MPEP 503) (Should be specifically itemized)
- ☐ \*Small Entity ☐ Statement filed in prior application, Status still proper and desired
- ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed)
- ☒ Other: Express Mail Certification

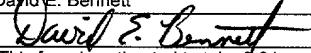
**\*NOTE FOR ITEMS 1 & 14: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).**

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information below and in a preliminary statement:
- |                                       |                                     |   |  |
|---------------------------------------|-------------------------------------|---|--|
| <input type="checkbox"/> Continuation | <input type="checkbox"/> Divisional | <input type="checkbox"/> Continuation-in-part (CIP) | of prior application No: _____ / _____ |
| Prior application information:        |                                     |   | Examiner: _____                        |
|                                       |                                     |   | Group/Art Unit: _____                  |

## 18. CORRESPONDENCE ADDRESS

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(Insert Customer No. or Attach bar code label here)

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ADDRESS			
CITY	STATE	ZIP CODE	
COUNTRY	TELEPHONE	FAX	

Name (Print/Type)	David E. Bennett	Registration No. (Attorney/Agent)	32,194
Signature		Date	November 27, 2000

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231.

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<b>FEE TRANSMITTAL</b>		<i>Complete if Known</i>	
Patent fees are subject to annual revision on October 1 These are the fees effective December 29, 1999. Small Entity payments <u>must</u> be supported by a small entity statement. otherwise large entity fees must be paid. See Forms PTO/SB/09-12. See 37 C.F.R. §§ 1.27 and 1.28.		Application Number	TBA
		Filing Date	TBA
		First Named Inventor	Esaam Sourour
		Examiner Name	TBA
		Group Art Unit	TBA
TOTAL AMOUNT OF PAYMENT	\$1,046.00	Attorney Docket No.	4015-784

METHOD OF PAYMENT (check one)	FEE CALCULATION (continued)																																																																																																																																																																																										
<p>1. <input checked="" type="checkbox"/> The Commission is hereby authorized to charge indicated fees and credit any over payments to:</p> <p>Deposit Account Number: 18-1167</p> <p>Deposit Account Name: Coats &amp; Bennett, P.L.L.C.</p> <p><input checked="" type="checkbox"/> Charge Any Additional Fee Required Under 37 CFR §§1.16 and 1.17      <input type="checkbox"/> Charge the Issue Fee Set in 37 CFR §1.18 at the Mailing of the Notice of Allowance</p> <p>2. <input checked="" type="checkbox"/> Payment Enclosed:  <input checked="" type="checkbox"/> Check    <input type="checkbox"/> Money Order    <input type="checkbox"/> Other</p>	<p><b>3. ADDITIONAL FEES</b></p> <table border="1" style="width:100%; border-collapse: collapse;"> <thead> <tr> <th>Large Fee Code</th> <th>Entity Fee (\$)</th> <th>Small Fee Code</th> <th>Entity Fee (\$)</th> <th>Fee Description</th> <th>Fee Paid</th> </tr> </thead> <tbody> <tr><td>105</td><td>130</td><td>205</td><td>65</td><td>Surcharge - late filing fee or oath</td><td></td></tr> <tr><td>127</td><td>50</td><td>227</td><td>25</td><td>Surcharge - late provisional filing fee or cover sheet</td><td></td></tr> <tr><td>139</td><td>130</td><td>139</td><td>130</td><td>Non-English specification</td><td></td></tr> <tr><td>147</td><td>2,520</td><td>147</td><td>2,520</td><td>For filing a request for reexamination</td><td></td></tr> <tr><td>112</td><td>920*</td><td>112</td><td>920*</td><td>Requesting publication of SIR prior to Examiner action</td><td></td></tr> <tr><td>113</td><td>1,840*</td><td>113</td><td>1,840*</td><td>Requesting publication of SIR after Examination action</td><td></td></tr> <tr><td>115</td><td>110</td><td>215</td><td>55</td><td>Extension for reply within first month</td><td></td></tr> <tr><td>116</td><td>380</td><td>216</td><td>190</td><td>Extension for reply within second month</td><td></td></tr> <tr><td>117</td><td>870</td><td>217</td><td>435</td><td>Extension for reply within third month</td><td></td></tr> <tr><td>118</td><td>1,360</td><td>218</td><td>680</td><td>Extension for reply within fourth month</td><td></td></tr> <tr><td>128</td><td>1,850</td><td>228</td><td>925</td><td>Extension for reply within fifth month</td><td></td></tr> <tr><td>119</td><td>300</td><td>219</td><td>150</td><td>Notice of Appeal</td><td></td></tr> <tr><td>120</td><td>300</td><td>220</td><td>150</td><td>Filing a brief in support of an appeal</td><td></td></tr> <tr><td>121</td><td>260</td><td>221</td><td>130</td><td>Request for oral hearing</td><td></td></tr> <tr><td>138</td><td>1,510</td><td>138</td><td>1,510</td><td>Petition to institute a public use proceeding</td><td></td></tr> <tr><td>140</td><td>110</td><td>240</td><td>55</td><td>Petition to revive - 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SUBMITTED BY				Complete (if applicable)	
Typed or Printed Name	David E. Bennett			Reg. Number	32,194
Signature				Date	11-27-00
				Deposit Account User ID	18-1167

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: )  
)  
Essam Sourour )  
)  
Serial No. \_\_\_\_\_ )  
)  
Filed: \_\_\_\_\_ )  
)  
For: MULTIPATH INTERFERENCE )  
REDUCTION FOR A CDMA SYSTEM )  
)  
)  
Attorney's Docket No. P-4015.784 )

**Express Mail Certification  
Label No.EL659733665US**

Raleigh, North Carolina

November 27, 2000

Assistant Commissioner for Patents

**BOX PATENT APPLICATION**

Washington, D.C. 20231

Sir:

**EXPRESS MAIL CERTIFICATE LABEL NO. EL659733665US**

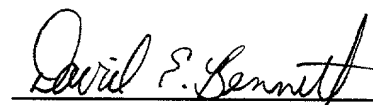
**DATE MAILED: November 27, 2000**

I hereby certify that the enclosed Utility Patent Application Transmittal, Fee Transmittal Form (2 copies), specification and claims, drawings (1 set of 10 sheets), Declaration and Power Of Attorney, Assignment and Recordation Sheet, and our Check # 3097 in the amount of \$1,046.00, are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. §1.10 on the date indicated above and is addressed to Assistant Commissioner for Patents, BOX PATENT APPLICATION, Washington, D.C. 20231.

Respectfully submitted,

**COATS & BENNETT, P.L.L.C.**

By:



David E. Bennett

Registration No. 32,194

Telephone: (919) 854-1844

Variable	Mean	SD	Min	Max
Age	34.5	10.2	21	55
Gender	0.5	0.5	0	1
Marital status	0.6	0.5	0	1
Education	12.5	1.5	9	16
Income	1500	500	500	3000
Health status	0.8	0.2	0	1
Smoking status	0.3	0.5	0	1
Alcohol consumption	0.2	0.4	0	1
Exercise frequency	0.5	0.5	0	1
Stress level	0.7	0.3	0	1
Sleep quality	0.6	0.4	0	1
Work satisfaction	0.5	0.5	0	1
Life satisfaction	0.6	0.4	0	1
Overall health	0.7	0.3	0	1
Physical health	0.8	0.2	0	1
Mental health	0.6	0.4	0	1
Social health	0.5	0.5	0	1
Emotional health	0.6	0.4	0	1
Behavioral health	0.5	0.5	0	1
Environmental health	0.4	0.6	0	1
Occupational health	0.5	0.5	0	1
Financial health	0.4	0.6	0	1
Family health	0.5	0.5	0	1
Community health	0.4	0.6	0	1
National health	0.5	0.5	0	1
Global health	0.4	0.6	0	1
World health	0.5	0.5	0	1
Universal health	0.4	0.6	0	1
Human health	0.5	0.5	0	1
Planetary health	0.4	0.6	0	1
Ecological health	0.5	0.5	0	1
Environmental health	0.4	0.6	0	1
Climate health	0.5	0.5	0	1
Weather health	0.4	0.6	0	1
Seasonal health	0.5	0.5	0	1
Monthly health	0.4	0.6	0	1
Daily health	0.5	0.5	0	1
Hourly health	0.4	0.6	0	1
Minute health	0.5	0.5	0	1
Second health	0.4	0.6	0	1
Micro health	0.5	0.5	0	1
Nano health	0.4	0.6	0	1
Pico health	0.5	0.5	0	1
Femto health	0.4	0.6	0	1
Atto health	0.5	0.5	0	1
Zepto health	0.4	0.6	0	1
Yocto health	0.5	0.5	0	1
Planck health	0.4	0.6	0	1
Schrodinger health	0.5	0.5	0	1
Einstein health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
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Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5	0	1
Kepler health	0.4	0.6	0	1
Newton health	0.5	0.5	0	1
Galileo health	0.4	0.6	0	1
Copernicus health	0.5	0.5		

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## MULTIPATH INTERFERENCE REDUCTION FOR A CDMA SYSTEM

### BACKGROUND OF THE INVENTION

The present invention relates generally to Code Division Multiple Access (CDMA) systems and, more particularly, to reducing multipath interference in a received CDMA signal.

10

Different types of wireless communication systems have adopted various schemes for supporting as many simultaneous users as possible. Code Division Multiple Access (CDMA) is one such scheme. CDMA is a technique employed in spread spectrum communications systems that allows multiple users to simultaneously share the same frequency. In CDMA systems, a wideband spreading signal is used to convert a narrowband data signal into a wideband signal for transmission. Direct sequence spread spectrum systems use a pseudo noise (PN) sequence to spread the data signal into a wideband signal.

15

Modulation of the PN sequence by the data sequence may be achieved by, for example, applying the data sequence and the PN sequence to a product modulator or multiplier. Multiplication of two signals produces a resultant signal whose frequency spectrum is equal to the convolution of the frequency spectrum of the two signals being multiplied. Thus, multiplying the wideband PN sequence signal with the relatively narrowband data signal produces a wideband signal whose spectrum is nearly equal to the spectrum of the PN signal.

20

CDMA permits multiple users to simultaneously use the same frequency by assigning to each user a different PN code selected from a set of orthogonal codes. Transmissions to and from individual users are spread using their assigned PN codes. Thus, an individual user's signal may be recovered using his or her assigned spreading code from the combined CDMA signal. With orthogonal spreading codes, the cross-correlation between different signals spread using different codes is nominally zero. Thus, correlating a received CDMA signal, which contains signals for all active users sharing that frequency, with a given user's PN code results in recovery of the narrowband data signal spread with that user's PN code. Data signals

30

5 intended for the other active users are not de-spread by correlation, and appear as wideband noise.

In CDMA systems using orthogonal codes and relatively long spreading code sequences with respect to transmitted data symbol timing, receivers can exploit these favorable code cross-correlation properties to increase receiver performance. Improvements in performance may be  
10 had even in the presence of unfavorable reception conditions, such as in multipath environments. Multipath reception commonly occurs in mobile terminals where numerous and changing obstructions intervene between the transmitter and the mobile terminals. In these cases, the transmitted CDMA signal travels to a given mobile terminal through a number of different propagation paths, with each path having different path characteristics, such as path  
15 length, phase, and attenuation.

RAKE receivers are frequently used in CDMA systems, and can exploit multipath reception in many circumstances to improve reception performance. RAKE receivers accomplish this by separately processing a selected number of the multipath versions of the CDMA signal received by the mobile receiver, and then coherently combining the data signals  
20 recovered from the selected multipath signals to form an overall RAKE receiver output signal with an improved signal-to-noise plus interference ratio (SNIR). RAKE receivers conventionally comprise some number of RAKE "fingers." Each RAKE finger is adapted to correlate the received CDMA signal with a commonly assigned PN code. Each RAKE finger is time-adjusted to align it with a different one of the multipath versions of the CDMA signal received by the  
25 mobile receiver.

The time-alignment essentially "shifts" each RAKE finger in correspondence with a relative propagation path delay for one of the selected propagation paths. Propagation paths are generally selected based on signal strength, and a typical RAKE receiver includes only a limited number of RAKE fingers, which in operation are aligned with the most significant  
30 multipath signals. The individual RAKE finger outputs are typically weighted based on the

5 propagation path characteristics of the corresponding multipath channels, and then coherently combined to form the overall RAKE receiver output signal. Conventional RAKE receiver techniques generally work best in environments where the total number of simultaneous users occupying the same frequency is not too great. As the number of simultaneous users increases, the amount of interference arising from the multipath signals influencing each other  
10 increases.

### BRIEF SUMMARY OF THE INVENTION

The present invention comprises a method and system for improving receiver performance under multipath reception conditions in CDMA-based mobile communication  
15 systems. A base station transmits a CDMA forward link signal that is received by one or more mobile terminals. Typically, an individual mobile terminal receives the transmitted signal through a number of propagation paths, giving rise to multipath interference in the received CDMA signal. The mobile terminal includes a modified RAKE receiver that reduces multipath interference in the received CDMA signal.

20 The modified RAKE receiver comprises a primary RAKE function and interference estimation RAKE function. The primary RAKE includes one or more primary RAKE fingers, with each primary RAKE finger time aligned in accordance with a propagation path delay associated with a propagation path through which the received CDMA signal is received. The primary RAKE fingers each recover the user's signal of interest by correlating the received CDMA signal  
25 with the user's assigned PN code sequence at a time offset corresponding to the finger's respective propagation path. The output signals from the primary RAKE fingers are coherently combined to form a combined signal of interest.

5           The interference estimation RAKE function generates multipath interference estimates for each of the signals output by the primary RAKE fingers. After scaling and combining, all the path interference estimates are subtracted from the combined signal of interest to reduce multipath interference in the combined signal of interest. The particular order of combining and subtracting signals of interest and interference estimates may be adjusted in accordance with design needs. Generally, there are  $L$  primary RAKE fingers, each aligned to one of the  $L$  most significant propagation paths--those paths with the strongest signal. Each one of the primary RAKE fingers has a corresponding  $L - 1$  interference estimators within the interference estimation RAKE function, for a total of  $L*(L - 1)$  interference estimators. The ratio between primary RAKE fingers and interference estimators may be changed in accordance with design requirements.

Each interference estimator corresponds to a respective one of the primary RAKE fingers, in turn each one of the primary RAKE fingers is time aligned with a respective one of the propagation paths associated with the received CDMA signal. Thus, each interference estimator estimates the multipath interference in the signal of interest recovered by its respective primary RAKE finger arising from a remaining one of the multipath propagation paths. In general, each interference estimator comprises  $L - 1$  secondary RAKE fingers, but this ratio may be adapted as needed. Each secondary RAKE finger generates a multipath interference estimate by correlating the received CDMA signal at a time offset determined by path delay differences between the propagation path associated with its respective primary RAKE finger and a remaining one of the propagation paths associated with the received CDMA signal. Nominally, for  $L$  primary RAKE fingers there are  $L (L - 1)$  interference estimators, and  $(L - 1)$  secondary RAKE fingers within each interference estimator.



5           The multipath interference estimates generated by the interference estimators can be  
coherently combined and subtracted from a combined output taken from the primary RAKE  
fingers. Alternative combining and subtraction schemes include but are not limited to  
subtracting relevant interference estimates on a per primary RAKE finger basis, and then  
combining the interference-compensated primary RAKE finger signals to form a combined  
10   output signal of interest. In any case, the multipath interference estimates produce by the  
interference estimation RAKE are subtracted from the combined signal of interest produced by  
the primary RAKE to reduce multipath interference. The modified RAKE receiver determines  
appropriate scaling for the interference estimate produced by each second RAKE finger to  
insure that its subtraction from the combined signal of interest results in an actual reduction of  
15   interference in the combined signal of interest.

          Multipath interference reduction techniques employed by the modified RAKE receiver do  
not require knowledge of the number of simultaneous users, nor do the techniques require  
knowledge of any PN codes being used for the other users operating on the same frequency.  
Further, because multipath interference estimation in the modified RAKE receiver is based on  
20   channel estimates that are readily updateable based on the pilot channel included in the CDMA  
forward link signal, estimation is responsive enough to deal with fast fading conditions.

#### BRIEF DESCRIPTION OF THE DRAWINGS

          Figure 1 is a diagram of an exemplary wireless communications network in which the  
25   present invention may be advantageously employed.

          Figure 2 is a functional diagram of a mobile terminal implementing the modified RAKE  
receiver of the present invention for use in the wireless communications network of Figure 1.

5           Figure 3 is a functional diagram illustrating the processing performed by the digital modulator in the mobile terminal of Figure 2.

          Figure 4 is a functional diagram illustrating the processing performed by the digital demodulator in the mobile terminal of Figure 2.

10           Figure 5 is a functional diagram illustrating the modified RAKE receiver in the mobile terminal of Figure 2.

          Figure 6 is a diagram illustrating the mobile terminal of Figure 2 subjected to multipath reception.

          Figure 7 is a functional diagram illustrating exemplary details of the modified RAKE receiver of Figure 5 when the number of channel paths  $L = 3$ .

15           Figure 8 is a diagram illustrating time offset components in the received composite signal operated on by the modified RAKE receiver arising from multipath reception, with  $L = 3$ .

          Figure 9 is a functional diagram illustrating exemplary details of a primary RAKE finger used in the modified RAKE receiver of Figure 5.

20           Figure 10 is a functional diagram illustrating exemplary details of a secondary RAKE finger used in interference estimation provided by the modified RAKE receiver of Figure 5, when the number of channel paths  $L = 3$ .

## DETAILED DESCRIPTION OF THE INVENTION

25           Referring now to Figure 1, the present invention will be discussed in the context of a wireless communications network supporting over-the-air communications between mobile terminals 100 and stationary receivers generally known as base stations. For simplicity, the wireless communications network is depicted with only one base station 12 and associated antenna 14; however, a practical wireless communications network will include multiple base stations 12 to provide communications service to an extended area. The base station 12  
30           connects to a mobile switching center (MSC) 16 that connects with one or more external

5 networks 18, such as the Public Switched Telephone Network (PSTN), the Integrated Services  
Digital Network (ISDN), and/or the Internet. The base station 12 is located in and provides  
wireless communication services to a geographic region referred to as a cell. Generally, there  
is one base station 12 for each cell within a given wireless communications network. The  
wireless communications network can support communications between individual users of the  
10 mobile terminals 100, and between users of the mobile terminals 100 and other communication  
systems accessible through the external networks 18.

The present invention contemplates communications between the mobile terminals 100  
and the base station 12 based on direct sequence spread spectrum signaling employing CDMA  
techniques. Interim Standard 95 (IS-95) represents an example of CDMA-based signaling. IS-  
15 95 defines a wireless communications standard widely employed in North America, and in other  
parts of the world. While IS-95 represents an existing cellular communications standard,  
related, newer standards are under development by the Telecommunications Industry  
Association (TIA), as well as by other standards bodies and industry organizations. For  
example, Interim Standard 2000 known as "cdma2000," represents the next generation CDMA  
20 standard currently being developed in the United States. The European variant of this standard  
is referred to as Wideband CDMA (WCDMA), and is also under current development. These  
named standards represent only a few of the many relevant communications standards. It  
should be understood that the present invention could be adapted and employed in a variety of  
communications systems extending well beyond the CDMA-based applications discussed  
25 herein.

Figure 2 is a block diagram of a mobile terminal 100. The term "mobile terminal" as  
used herein includes a cellular radiotelephone; a Personal Communications System (PCS)  
terminal that may combine a cellular radiotelephone with data processing, facsimile and data  
communications capabilities; a Personal Digital Assistant (PDA) that can include a  
30 radiotelephone, pager, Internet/Intranet access, web browser, organizer, calendar; a

5 conventional lap top and/or palm top computer equipped with a radiotelephone transceiver, or other appliance that includes a radiotelephone transceiver. Mobile terminals may also be referred to as “pervasive computing” devices. The specific architecture of the mobile terminal 100 will vary depending upon the terminal’s range of features and specific intended use.

10 The mobile terminal 100 comprises a micro controller unit (MCU) 102, an RF transceiver 110, a digital signal processor (DSP) 150, and a user interface 190. The mobile terminal 100 may additionally include an external interface (not shown) for communication with the computer, local area network, or other device.

15 The RF transceiver 110 establishes a link between the mobile terminal 100 and the antenna 14 for wireless communications with the base station 12. The RF transceiver 110 comprises a receiver 120, a transmitter 130, a frequency synthesizer 140, an antenna coupling circuit 112, and an antenna 114. The receiver 120 and transmitter 130 are coupled to the antenna by the antenna coupling circuit 112. The antenna coupling circuit 112 may include a duplexer for isolating transmit and receive signal paths during full duplex receive and transmit operations, and may include a switch for multiplexing the antenna between the receiver 120 and 20 transmitter 130 during half-duplex receive and transmit operations. Transmit-band and receiver-band filters in the duplexer provide the necessary isolation between receive and transmit signal paths in the RF transceiver 110.

The receiver 120 receives a downlink or a forward link communications signal from the base station 12. Within a given cell, a number of mobile terminals 100 receive the same 25 forward link CDMA signal from a common base station 12. In a given mobile terminal 100, the receiver 120 receives the CDMA forward link signal, amplifies and down converts the received signal to a base band frequency of the DSP 150. Signals converted by the receiver 120 to the base band frequency are referred to herein as base band signals. Thus, the receiver 120 provides the DSP 150 with a base band received CDMA signal  $r(t)$ . The transmitter 130 sends 30 an up link or reverse link communications signal to the base station 12. The transmitter 130

5 receives base band signals from the DSP 150, which the transmitter 130 amplifies and uses to modulate an RF carrier at a directed power level.

The frequency synthesizer 140 provides reference signals used for frequency translation in the receiver 120 and the transmitter 130.

The DSP 150 comprises a source coder/decoder 160 and a digital modem 155. A  
10 speech coder is included within the source coder/decoder 160 for digitizing and coding speech for transmission on the reverse link to the base station 12. Additionally, the speech coder decodes speech signals received from the base station 12 and converts speech signals into audio signals that are output to the speaker 194.

15 The digital modem 155 processes digital signals to make communications between the mobile terminal and the base station 12 more robust. The digital modem includes a digital modulator 170 (Figure 4) and a demodulator 180 (Figure 5).

20 The MCU 102 supervises the operation of the mobile terminal and administers the procedures associated with the communication protocol being used. The MCU 102 typically comprises a microprocessor and supporting peripherals facilitating control of the mobile terminal. Peripherals typically include timer/counter units, pulse-width modulation (PWM) generators, bit-directed input/output, serial communications interfaces, and other modules for flexibly interfacing the microprocessor with various other circuitry within the mobile terminal. The microprocessor may include hardware computational units for accelerating certain mathematical operations, such as division and squaring.

25 Typically, the MCU 102 assigns timers to track network time and uses that information to assist in synchronizing the mobile terminal 100 with the required transmit and receive signal timing. The timing information may be used to identify frame boundaries and slot indexes associated with the received CDMA signal. The MCU 102 also uses timers to trigger specific tasks as the mobile terminal 100 transitions to different operating modes, such as sleep,

5 receive, and talk. The MCU 102 uses register files to store calibration data, the electronic serial number (ESN) of the user (used to authenticate the user), and to other non-volatile information.

The MCU 102 also implements the communication protocols used by the mobile terminal 100. The communication protocol specifies timing, multiple access approach, modulation format, frame structure, power level, as well as many other aspects of mobile terminal  
10 operation. The MCU 102 inserts signaling messages into the transmitted signals sent to the base station 12 and extracts signaling messages from the received signals. The MCU 102 acts on signaling messages received from the base station 12 as set forth in the communication protocol. When the user enters commands via the user interface 190, the commands are passed to the MCU 102 for action. The MCU 102 also provides power management to the  
15 mobile terminal 100. Power management includes monitoring battery energy levels, charging the battery, and minimizing power consumption by changing modes. In general, there are three modes of operation for the mobile terminal 100: idle, receive, and talk. In idle mode, the MCU 102 deactivates most functions except the digital system clock. In receive mode the MCU 102 activates the receiver 120 and the digital modem 155. It further demodulates the paging  
20 channel in the received CDMA signal until it receives a valid paging message and then switches to talk mode. In talk mode, the entire mobile terminal 100 is activated to support two-way communication.

The MCU 102 and DSP 150 use dedicated or shared buses to connect to memory (not shown). Memory is typically segmented into blocks that hold the start-up code, control software,  
25 DSP firmware, and temporary data.

Figure 3 is a functional block diagram illustrating the processing performed by the digital modulator 170 in a CDMA mobile terminal 100. The digital modulator 170 comprises a convolutional encoder 171, a repeater 172, a block interleaver 173, a Walsh code generator 175, a randomizer 176, a pseudo noise generator 177, an adder 178 and an IQ modulator 179.  
30 An information source, such as the user interface 190, provides an information signal, such as

5 speech or facsimile signals to the source coder/decoder 160, which converts the information  
signal into digital form. The output of the source coder/decoder 160 is applied to an error  
correction coder to render transmissions more tolerant to noise and interference. The error  
correction encoder, may, for example, comprise the convolutional encoder 171. The error  
correction coder adds controlled redundancy to the source encoded bits to aid in the detection  
10 and correction of errors that occur during transmission. Detailed discussion of the processing  
performed by the digital modulator 170, including operation of the Walsh modulator 175, the  
randomizer 176, and the PN generator 177, is not critical to understanding the present  
invention. However, the PN generator 177 may provide the assigned PN sequence to other  
functions within the mobile terminal 100.

15 Figure 4 is a block diagram showing the digital demodulator 180 for a CDMA mobile  
terminal 100. The digital demodulator 180 comprises a searcher 182 and associated set  
maintenance list 182A, a delay tracker 183, a rake receiver 200 according to the present  
invention, an automatic frequency control function (AFC) 184, an automatic gain control function  
(AGC) 185, a summing circuit 186, a de-interleaver 187, and a decoder 188.

20 The searcher 182 identifies the significant propagation path signals from the active base  
station 12 based on pilot channel information included in the received CDMA signal. The pilot  
channel has known characteristics and allows the searcher to make rough determinations for  
the relative delay offsets  $\{\tau\}$  of each of the identified propagation paths. Because the pilot  
channel is a known signal, the propagation path characteristics for each of the propagation  
25 paths may be estimated, including path gain and phase characteristics. The propagation path  
delay information determined by the searcher 182 is provided to the delay tracker 183, which  
further refines the delay estimates  $\{\tau\}$  such that the PN code sequence used by the RAKE  
receiver 200 may be synchronized with the propagation paths of interest.

5           The delay tracker 183 also includes tracking hardware that allows the mobile terminal to keep its RAKE receiver 200 aligned with the propagation paths' potentially changing path delays. The searcher 182 also provides information regarding the set maintenance list 182A, which includes stored lists of active, neighboring, and remaining base stations 12 relevant to the current geographic position of the mobile terminal 100. As will be explained in more detail, the  
10       RAKE receiver 200 correlates the received CDMA signal  $r(t)$  with the user's assigned PN code and Walsh code to recover the signal of interest (the user's intended data signal) from the received CDMA signal  $r(t)$ . The recovered signal of interest still includes interleaving and error coding and must therefore pass through the de-interleaver 187 and the decoder 188 before the actual data signal is recovered.

15           The digital demodulator 180 provides two signals that are used to track the strength and carrier frequency of the received CDMA signal. The automatic gain control (AGC) loop adjusts the gain of the receiver 120 to overcome fading effects of the propagation channel. The automatic frequency control (AFC) loop corrects the RF synthesizer 140 to obtain the proper base band frequency after down conversion by the receiver 120.

20           Figure 5 provides top-level illustration of the RAKE receiver 200 contemplated by the present invention. The RAKE receiver 200 may be thought of as two halves, with the primary RAKE 202 operative to recover the signal of interest from the received CDMA signal  $r(t)$ , and the interference estimation RAKE 204 operative to generate interference estimates arising from multi-path reception of the received CDMA signal. In general operation, the interference  
25       estimates produced by the interference estimation RAKE 204 are subtracted from the combined signal of interest output by the primary RAKE 202 using a summing circuit 206 to reduce multi-path interference in the combined signal of interest.



5           Figure 6 illustrates the problem of multipath reception in a mobile communications environment. The mobile terminal 100 is subjected to multi-path reception arising from various obstacles in and around its reception and environment. More particularly, the radio signal transmitted by the antenna 14 associated with the base station 12 travels through a number of different propagation paths depending upon the environmental surroundings relevant to the  
10   fixed position of the base station 12 and the variable position of the mobile terminal 100. Obstacles commonly include buildings and geographic features, as well as other types of structures and obstructions. The radio signals transmitted from the base station antenna 14 may have a direct, line-of-site path to the mobile terminal 100, but will usually also travel to the mobile terminal 100 via alternate propagation paths induced by the radio signal reflecting from  
15   various obstructions.

          In the example illustrated, the mobile terminal 100 receives the signal transmitted by the antenna 14 through three propagation paths, path 1, path 2, and path 3. Thus, the received CDMA signal  $r(t)$  operated on by the RAKE receiver 200 includes multipath components associated with path 1, path 2, and path 3. The received CDMA signal  $r(t)$  may be considered a  
20   composite of its various multipath signal components. Each propagation path has particular characteristics regarding radio signal attenuation, phase change, and mobile terminal arrival time. The multi-path components of the received CDMA signal have different arrival times due to the different path lengths of the various propagation paths. While the illustration depicts three radio signal propagation paths, in practice the mobile terminal 100 may receive the transmitted  
25   signal through any number of propagation paths. Typically, only a select number of these propagation paths will be significant in terms of signal strength from the perspective of the mobile terminal 100.

          Figure 7 provides details for the modified RAKE receiver 200 introduced in Figure 5. The primary RAKE 202 includes one or more primary RAKE fingers 210 and an associated  
30   summing circuit 212. The interference estimation RAKE 204 includes one or more interference

5 estimators 214, along with a corresponding number of scaling multipliers 216, and a summing circuit 218. As illustrated, the RAKE receiver 200 of the present invention is configured to accommodate three propagation paths (paths 1, 2, and 3). It should be understood that the RAKE receiver 200 may be configured for any desired number of propagation paths.

10 In general, to accommodate  $L$  propagation paths, the primary RAKE 202 will include  $L$  primary fingers 210, while the interference estimation RAKE 204 will include  $L * (L-1)$  interference estimators 214. However, the basic formula for determining the number of interference estimators 214 needed in proportion to the number of primary RAKE fingers 210 may be changed or altered as needed, or as design restraints require. For example, hardware constraints may require that the total number of interference estimators 214 be reduced. In  
15 such cases, the interference estimation RAKE 204 would be scaled back to estimate interference for only a selected number of the primary RAKE fingers 210.

20 In operation the primary RAKE 202 is configured such that each one of the primary RAKE fingers 210 is assigned to one of the propagation paths of interest. Each primary RAKE finger 210 correlates the received CDMA signal at a time offset corresponding to a path delay associated with the assigned propagation path of that primary RAKE finger 210. Each primary RAKE finger 210 may be time-aligned in a number of ways. For example, the primary RAKE fingers 210 might share delay elements (not shown) such that the received CDMA signal  $r(t)$  could be appropriately delayed or time offset by values corresponding to the various propagation path delays of interest, and then these time adjusted versions of the received  
25 CDMA signal  $r(t)$  could be provided to the corresponding primary RAKE fingers 210.

Alternatively, the PN code and Walsh code sequences supplied to each of the primary RAKE fingers 210 and used in their correlation operations can be offset by an amount corresponding to the propagation path delay associated with the particular primary RAKE finger 210.

Offsetting the PN code and Walsh code sequences in this manner is often times referred to as

5 “code phase offsetting.” By offsetting the PN code and Walsh code sequences, it may be more practical to include delay elements within each of the primary RAKE fingers 210.

Figure 8 illustrates the effect of time shifting the PN code sequence in the three primary RAKE fingers 210. The received CDMA signal  $r(t)$  is correlated by the first primary RAKE finger 210 over a correlation window at time offset  $\tau_1$  corresponding to path 1. The second and third  
10 primary RAKE fingers 210 correlate the same received CDMA signal  $r(t)$  at relative time offsets  $\tau_2$  and  $\tau_3$ , corresponding to paths 2 and 3, respectively. The received CDMA signal  $r(t)$  represents a composite of the multi-path components arising from receiving the transmitted signal through the various propagation paths.

Referring again to Figure 7, the RAKE receiver 200 receives the currently assigned PN  
15 code sequence, the set of propagation path relative delay values  $\{\tau\}$ , the set of propagation path channel coefficients  $\{\beta e^{j\gamma}\}$ , and a set of interference estimate scale factors  $\{\alpha\}$ . The values for  $\{\tau\}$  and  $\{\beta e^{j\gamma}\}$  may, for example, be provided by the delay tracker 183. The PN code sequence and the assigned Walsh code in IS-95 systems may, for example, be provided by the digital modulator 170. The primary RAKE 202 uses the relative delay values  $\{\tau\}$  to align each primary  
20 RAKE finger 210 in accordance with the propagation path delays. In the three-path example, the set of relative delay values  $\{\tau\}$  comprises  $\tau_1$ ,  $\tau_2$ , and  $\tau_3$  noted above. The set of channel coefficients  $\{\beta e^{j\gamma}\}$  comprises channel coefficients  $\beta_1 e^{j\gamma_1}$ ,  $\beta_2 e^{j\gamma_2}$ , and  $\beta_3 e^{j\gamma_3}$ , corresponding to propagation paths 1, 2, and 3, respectively. The  $\beta$  values represent a magnitude value corresponding to path gain, while the  $\gamma$  values represent propagation path phase shifts. Both  
25 the primary RAKE 202 and the interference estimation RAKE 204 use the set of delay values  $\{\tau\}$  and the set of channel coefficients  $\{\beta e^{j\gamma}\}$ .

Additionally, the interference estimation RAKE 204 receives a set of scale values  $\{\alpha\}$  representing multipath interference estimate signal scaling factors that are explained in more detail later. In the three-path example, the set of scaling factors  $\{\alpha\}$  comprises  $\alpha_{1,2}$ ,  $\alpha_{1,3}$ ,  $\alpha_{2,1}$ ,

5  $\alpha_{2,3}$ ,  $\alpha_{3,1}$ , and  $\alpha_{3,2}$ , corresponding to scaling factors for each propagation path with respect to the remaining propagation paths.

Figure 9 illustrates a primary RAKE finger 210. The primary RAKE finger 210 includes a correlator 220 for correlating the received CDMA signal  $r(t)$  with the PN code sequence at offset  $\tau_i$  and a multiplier 222 for multiplying the received CDMA signal  $r(t)$  by the appropriate channel  
10 coefficient  $\beta_i e^{j\gamma_i}$ , where the subscript  $i$  denotes the particular propagation path to which the primary RAKE finger 210 is aligned. As noted, the primary RAKE finger 210 may be time aligned to a specific one of the propagation paths by either delaying the received CDMA signal or delaying the PN code sequence. Thus, the correlator can use the appropriate one in the set of path delay values  $\{\tau\}$  to offset the PN code sequence and Walsh code by an amount related  
15 to the path delay of the corresponding propagation path. The output from the multiplier 222 is termed the "signal of interest," and includes multipath interference arising from the other propagation paths that becomes increasingly worse as the number of simultaneous users of nearby mobile terminals 100 increases.

Each of the primary RAKE fingers 210 multiplies its correlator output signal by the  
20 complex conjugate of the corresponding channel coefficient  $\beta_i e^{j\gamma_i}$  so that the signals of interest output by each primary RAKE finger 210 may be coherently combined together in the summing circuit 212 to produce a combined signal of interest.

Figure 10 provides details for a selected one of the interference estimators 214 included in the interference estimation RAKE 204. The interference estimator 214 includes secondary  
25 fingers 224, a summing circuit 230, and multipliers 232 and 234. The secondary fingers 224 each include a correlator 226 and a multiplier 228. As illustrated, the interference estimator 214 is configured to estimate multipath interference arising from propagation path 2 in the signal of interest recovered by the primary RAKE finger 210 that is aligned with propagation path 1. Thus, the illustration continues the three-path example. As noted, each interference estimator

5 214 nominally includes  $L - 1$  secondary RAKE fingers 224. In this context, first and second propagation path references do not necessarily imply a first and second delay relationship between the first and second propagation paths, rather the terms are used for convenient reference. In the illustrated example, the multipath interference arising from path 2 is determined using correlation time offsets relative to paths 1 and 3.

10 The upper secondary RAKE finger 224 is configured to correlate the received CDMA signal a time offset determined based on a difference between path delays corresponding to the first and second propagation paths. Referring back to Figure 8, the upper secondary RAKE finger 224 is configured to correlate the received CDMA signal at a time offset determined as  $\tau_1 - (\tau_2 - \tau_1)$ , which is equivalent to correlating the received CDMA signal over a correlation window  
15 that is shifted backwards from time  $\tau_1$  by an amount equal to the arrival time offset between propagation paths 1 and 2. This arrival time difference may be measured as the difference between  $\tau_1$  and  $\tau_2$ .

Similarly, the lower secondary RAKE finger 224 is configured to correlate the received CDMA signal at time offset determined based on a difference between path delays  
20 corresponding to the first, second, and third propagation paths. Specifically, the correlator 226 in the lower secondary RAKE finger 224 is configured to correlate the received CDMA signal at time offset given by  $\tau_3 - (\tau_2 - \tau_1)$ , which is equivalent to correlating the received CDMA signal over a correlation window that is shifted backwards from time  $\tau_3$  by an amount equal to the propagation path delay difference between propagation paths 2 and 1. This difference is  
25 expressed as  $\tau_2 - \tau_1$ .

The upper secondary RAKE finger 224 is configured to multiply its correlation result with a channel gain that is the complex conjugate of the channel gain applied by the primary RAKE finger aligned with propagation path 1. Similarly, the lower secondary RAKE finger 224 is configured to multiply its correlation result by the complex conjugate of the channel gain applied

5 by the primary RAKE finger aligned with propagation path 3. Multiplication of the correlation results output from the secondary RAKE fingers 224 allows the interference estimates to be coherently combined by summing circuit 230.

Thus, the interference estimate output by the upper secondary RAKE finger 224 may be expressed as the correlation result  $C(\tau_1 - (\tau_2 - \tau_1))$  multiplied by the complex conjugate of the path 1 channel coefficient,  $\beta_1 e^{-j\gamma_1}$ . Similarly the interference estimate output by the lower secondary RAKE finger 224 may be expressed as the correlation result  $C(\tau_3 - (\tau_2 - \tau_1))$  multiplied by the complex conjugate of the path 1 channel coefficient,  $\beta_1 e^{-j\gamma_1}$ . These two interference estimates must be added to produce a combined interference estimate for path 1 with respect to path 2. Using maximum ratio combining, the two interference estimates may be coherently combined to form  $I_{1,2}$  as,

$$I_{1,2} = \left[ \frac{C(\tau_1 - (\tau_2 - \tau_1))\beta_1 e^{-j\gamma_1} + C(\tau_3 - (\tau_2 - \tau_1))\beta_3 e^{-j\gamma_3}}{\beta_1^2 + \beta_3^2} \right] \beta_2 e^{j\gamma_2} \beta_1 e^{-j\gamma_1}$$

The above equation may be generalized for  $I_{f,l}$ , which represents the interference on the primary RAKE finger 210 aligned with propagation path  $f$  arising from propagation path  $l$ , as,

$$I_{f,l} = \left[ \frac{\sum_{m=1}^L C(\tau_m - (\tau_l - \tau_f))\beta_m e^{-j\gamma_m}}{\sum_{m=1}^L \beta_m^2} \right] \beta_l e^{j\gamma_l} \beta_f e^{-j\gamma_f}, \quad m \neq l.$$

The combined multipath interference estimate output from the summing circuit 230 is multiplied by the inverse sum of the signal powers for all propagation paths but the one for which the interference estimate is being developed. Thus, in the illustrated example, interference estimates are being developed for propagation path 2, so the signal powers for paths 1 and 3 are summed and inverted and then used to multiply the combined interference

5 estimate in multiplier 232. This action creates a unity-power multipath interference estimate signal. The unity-power multipath interference estimate signal must then be scaled in accordance with the channel coefficients for the propagation paths involved. Here, the estimate for the interference in the propagation path 1 signal arising from the propagation path 2 signal is being developed, so the channel coefficient corresponding to paths 1 and 2 are used. Thus,  
10 multiplier 234 multiplies the unity-power multipath interference estimate signal by  $\beta_2 e^{j\gamma_2} * \beta_1 e^{-j\gamma_1}$ .

This action generates the estimated multipath interference signal,  $I_{1,2}$ , where  $I_{1,2}$  denotes the interference in the signal of interest produced by the primary RAKE finger 210 aligned to path 1 arising from path 2. In general, the interference estimation RAKE 204 generates  $L(L - 1)$  multipath interference signals, generically denoted as  $I_{f,l}$ , where  $f = 1 \dots L$ ,  $l = 1 \dots L$ , and  $f \neq l$ .  
15 This expression represents the interference estimate arising from the  $l$  propagation path for the signal of interest recovered from the primary RAKE finger 210 aligned with propagation path  $f$ .

The remaining interference estimators have similar structures that are configured with path delay and channel coefficient values that are in accordance with their respective primary RAKE fingers. The individual multipath interference outputs  $I_{f,l}$  from all of the interference  
20 estimators 214 pass through individual multipliers 216 which effect a desired scaling prior to subtracting the interference estimates from the combined output of the primary RAKE 202.

The interference estimation technique employed by the interference estimation RAKE 204, could, absent proper care, result in adding additional interference to the combined output of the primary RAKE 202. This possibility principally arises from the correlation window shifting  
25 employed by the individual interference estimators 214. Because the correlation window shifts used in the interference estimators 214 are not necessarily time aligned to symbol boundaries in the received CDMA signal, correlation results include correlations across symbols, which may result in additional interference. Thus, the interference estimation RAKE 204 employs one of several techniques to arrive at a set of scaling factors that ensure the scaled versions of the

5      multipath interference estimates  $I_{f,l}$  produced by the interference estimators 214 accomplish the desired function of reducing, or at least not adding interference to the combined output signal from the primary RAKE 202.

One technique for accomplishing the above goal is to select the  $\alpha$ 's based on maximizing the overall signal to noise plus interference ratio (SNIR) in the combined signal of interest output by the primary RAKE 202 after subtraction of the combined interference estimate output by the interference estimation RAKE 204. Alternately, the SNIR for individual primary RAKE fingers 210 may be maximized. A simpler technique for accomplishing this is to set each  $\alpha_{f,l}$  (the scaling applied to  $I_{f,l}$ ) as a ratio of the interference power and the sum of the interference power and non-interference power for each primary RAKE finger with respect to the propagation path to which the particular interference estimator 214 is concerned with. Thus,  $\alpha_{f,l}$ , which is the scaling factor to be applied to  $I_{f,l}$ , may be determined as,

$$\alpha_{f,l} = \frac{P_x}{P_x + P_y}$$

Where a first component of  $I_{f,l}$  is  $x$ , where  $x$  is the interference that is desired to be subtracted from the primary RAKE finger 210 aligned with propagation path  $f$  caused by propagation path  $l$ . Component  $x$  has a signal power expressed as  $P_x$ . A second component  $y$  denotes residual terms in  $I_{f,l}$  that are not interference terms in the primary RAKE finger 210 aligned with propagation path  $f$ . Component  $y$  has a signal power expressed as  $P_y$ . The subtraction of  $I_{f,l}$  removes the interference term  $x$  from the signal of interest output by the respective primary RAKE finger 210 aligned with path  $f$ . However, this subtraction adds the residual component  $y$ , which was not part of the original interference. Selecting  $\alpha_{f,l}$  in accordance with the above equation, insures that the subtraction process adds less interference power than it subtracts.

The present invention may, of course, be carried out in other specific ways than those herein set forth without departing from the spirit and essential characteristics of the invention.



- 5 The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive, and all changes coming within the meaning and equivalency range of the appended claims are intended to be embraced therein.

5

## CLAIMS

What is claimed is:

1. A method of reducing multipath interference in a received composite signal comprising a plurality of multipath signals, the method comprising:
  - correlating the received composite signal with a PN code sequence at a time offset
  - 10 corresponding to a first one of the plurality of propagation paths to recover a signal of interest from a first multipath signal;
  - correlating the received composite signal with the PN code sequence at a time offset corresponding to a delay difference between the first multipath signal and a second multipath signal to generate a multipath interference estimate;
  - 15 subtracting the multipath interference estimate from the signal of interest to reduce multipath interference.
2. The method of claim 1 further comprising:
  - 20 multiplying the signal of interest by a first channel coefficient determined for the first one of the plurality of propagation paths to adjust a gain and phase of the signal of interest; and
  - multiplying the multipath interference estimate by the first channel coefficient and by a second channel coefficient determined for the second one of the plurality of propagation paths before subtracting the multipath interference estimate from the
  - 25 signal of interest to adjust a gain and phase of the multipath interference estimate.
3. The method of claim 1 further comprising multiplying the multipath interference estimate by an interference scaling factor before subtracting the multipath interference estimate from the signal of interest.

5           4.       The method of claim 3 further comprising determining a value for the scaling factor by determining a ratio of multipath interference power in the signal of interest arising from the second multipath signal and residual interference power in the multipath interference estimate introduced during determination of the multipath interference estimate.

10           5.       The method of claim 3 further comprising determining a value for the scaling factor that maximizes the signal-to-noise plus interference ratio (SNIR) of the signal of interest.

6.       A method of reducing multipath interference in a received composite signal comprising a plurality of multipath signals, the method comprising:

15           correlating the received composite signal with a PN code sequence at relative time offsets corresponding to path delays associated with selected ones of the plurality of multipath signals to recover a signal of interest from each one of the selected multipath signals;

20           determining interference estimates for each one of the selected multipath signals caused by remaining ones of the selected multipath signals by correlating the received composite signal at time offsets corresponding to path delay differences between the multipath signals;

25           subtracting the interference estimates determined for the selected ones of the multipath signals from the signals of interest recovered from the selected ones of the multipath signals.

5           7.       The method of claim 6 further comprising coherently combining the signals of  
interest recovered from the selected ones of the multipath signals to form a combined signal of  
interest, and wherein subtracting the interference estimates determined for selected ones of the  
multipath signals from the signals of interest recovered from the selected ones of the multipath  
signals comprises subtracting the interference estimates from the combined signal of interest.

10           8.       The method of claim 6 wherein in determining an interference estimate for a first  
one of the selected multipath signals caused by a second one of the selected multipath signals,  
the step of determining interference estimates for each one of the selected multipath signals  
caused by remaining ones of the selected multipath signals by correlating the received  
15 composite signal at time offsets corresponding to path delay differences between the multipath  
signals comprises:

for all but the second multipath signal, generating a correlation output by correlating the  
received composite signal with the PN code sequence at a time offset corresponding  
to a current one of the selected multipath signals offset by a delay difference  
20 between the first and second ones of the selected multipath signals;  
compensating each correlation output using channel coefficients determined for the  
current one of the selected multipath signals;  
coherently combining each correlation output to form a raw estimate of the interference  
in the first multipath signal caused by the second multipath signal;  
25 multiplying the raw estimate by a power-scaling factor to adjust a power of the raw  
estimate;  
multiplying the raw estimate by a channel-scaling factor to scale the raw estimate with  
respect to the first and second multipath signals to form the interference estimate for  
multipath interference in the first channel with respect to the second channel.

5           9.     The method of claim 8 further comprising:  
  
scaling each of the interference estimates by a respective one in a set of interference  
estimate scalars;  
  
combining the interference estimates after scaling by the set of interference estimate  
scalars to form a combined interference estimate;  
  
10          combining the signals of interest to form a combined signal of interest; and  
  
subtracting the combined interference estimate from the combined signal of interest.

10.     The method of claim 9 further comprising:  
  
observing a characteristic dependent upon the signals of interest; and  
  
15          updating values of the set of interference estimate scalars based on the characteristic so  
  
as to minimize overall multipath interference in the combined signal of interest.

11.     The method of claim 6 further comprising:  
  
coherently combining the signals of interest to form a combined signal of interest;  
  
20          individually scaling each of the interference estimates with a respective one of a set of  
interference estimate scalars;  
  
combining the interference estimates after scaling by the set of interference estimate  
scalars to form a combined interference estimate; and  
  
subtracting the combined interference estimate from the combined signal of interest to  
  
25          reduce multipath interference in the combined signal of interest.

5           12.    The method of claim 11 further comprising:  
  
          monitoring the combined signal of interest after subtraction of the combined interference  
          estimate; and  
  
          adjusting values of the set of interference estimate scalars based on monitoring the  
          combined signal of interest to minimize a remaining amount of multipath interference  
10           in the combined signal of interest after subtraction of the combined interference  
          estimate.

15           13.    The method of claim 12 wherein adjusting values of the set of interference  
          estimate scalars based on monitoring the combined signal of interest to minimize a remaining  
          amount of multipath interference in the combined signal of interest after subtraction of the  
          combined interference estimate comprises:  
  
          determining a multipath interference power value and a residual interference power  
          value for each interference estimate scalar in the set of interference estimates  
          relevant to corresponding ones of the interference estimates; and  
20           setting a value of each interference estimate scalar based on a ratio involving the  
          respective multipath interference power value and residual interference power value;  
          wherein the ratio involving the multipath interference power value and residual  
          interference power value is adjusted to insure that the residual interference power  
          value is always less than the multipath interference power value.

25           14.    The method of claim 6 wherein for L selected ones of the plurality of multipath  
          signals, the step of determining interference estimates for each one of the selected multipath  
          signals caused by remaining ones of the selected multipath signals by correlating the received  
          composite signal at time offsets corresponding to path delay differences between the multipath  
30           signals comprises determining  $L - 1$  interference estimates for each one of the L selected

5      multipath signals, with each estimate for a current one of the L selected multipath signals  
representing an estimate of multipath interference in the current selected multipath signal  
caused by a remaining one of the selected multipath signals.

15      15.      The method of claim 14 further comprising performing  $L - 1$  offset correlations of  
10      the received composite signal for each one of the  $L - 1$  interference estimates, such that each  
one of the  $L - 1$  interference estimates generated for each one of the L interference estimates  
comprises a summation of  $L - 1$  correlation results.

15      16.      A RAKE receiver comprising:  
at least one primary RAKE finger, each adapted to recover a signal of interest from a  
selected multipath signal within a received composite signal comprising a plurality of  
multipath signals by correlating the received composite signal with a PN code at a  
time offset corresponding to the selected multipath signal;  
20      at least one interference estimator, each adapted to generate an interference estimate  
for a corresponding one of the at least one primary RAKE finger caused by a  
remaining one of the plurality of multipath signals with respect to the selected  
multipath signal from which the corresponding primary RAKE finger recovers the  
signal of interest; and  
a subtraction circuit for subtracting the interference estimates generated by the at least  
25      one interference estimator from the signals of interest recovered by the at least one  
primary RAKE finger.

5           17.     The RAKE receiver of claim 16 wherein the at least one primary RAKE finger  
comprises a plurality of primary RAKE fingers, each aligned to one of a selected set of multipath  
signals chosen from the plurality of multipath signals in the received composite signal and each  
adapted to output a recovered signal of interest, and further wherein the at least one  
interference estimator comprises a plurality of interference estimators, each adapted to  
10   generate an interference estimate for a corresponding one of the plurality of primary RAKE  
fingers.

15           18.     The RAKE receiver of claim 17 further comprising:  
a signal of interest combiner to combine the signals of interest to form a combined signal  
of interest; and  
an interference estimate combiner to combine the interference estimates to form a  
combined interference estimate;  
wherein the subtraction circuit is operative to subtract the interference estimates  
generated by the at least one interference estimator from the signals of interest  
20   recovered by the at least one primary RAKE finger by subtracting the combined  
interference estimate from the combined signal of interest.

25           19.     The RAKE receiver of claim 17 further comprising a plurality of interference  
estimate scalars, each adapted to multiply a respective one of the interference estimates by one  
in a set of interference estimate scale values in advance of the interference estimates being  
subtracted from the signals of interest in the subtraction circuit.



5           20.     The RAKE receiver of claim 16 wherein each one of the at least one interference  
estimators comprises:

10           a plurality of secondary RAKE fingers, each adapted to generate an individual estimate  
of multipath interference in a first one of the plurality of multipath signals arising from  
a second one of the plurality of multipath signals by correlating the received  
composite signal with the PN code sequence at time offset corresponding to a  
selected one of the plurality of multipath signals shifted by a relative delay difference  
between the first and second multipath signals, wherein the selected multipath signal  
is not the second multipath signal;

15           a first multiplier in each secondary RAKE finger adapted to multiply the individual  
estimate of multipath interference by a channel coefficient determined for the  
selected multipath signal on which the secondary RAKE finger operates;

          a combining circuit for combining the output from each secondary RAKE finger within the  
interference estimator to form a raw interference estimate;

20           a second multiplier adapted to multiply the raw estimate by a power-scaling value to  
form a power-scaled raw estimate;

          a third multiplier adapted to multiply the power-scaled raw estimate by a channel-scaling  
value to form the interference estimate output by the interference estimator.

25           21.     The RAKE receiver of claim 20 wherein there are L primary RAKE fingers  
corresponding to L selected multipath signals, and up to (L – 1) interference estimators for each  
one of the L primary RAKE fingers, each of the up to (L – 1) interference estimators  
corresponding to a given one of the L primary RAKE fingers adapted to estimate the  
interference in the selected multipath signal corresponding to the given primary RAKE finger  
arising from a remaining one of the L selected multipath signals.

5           22.     The RAKE receiver of claim 20 wherein the RAKE receiver is further adapted to  
determine the power-scaling value used in each of the at least one interference estimators  
based on propagation channel coefficients determined for relevant ones of the plurality of  
multipath signals.

10           23.     The RAKE receiver of claim 20 wherein the RAKE receiver is further adapted to  
determine the channel scaling value used in each of the at least one interference estimators  
based on propagation channel coefficients determined for the first and second multipath signals  
relevant to a given one of the at least one interference estimator.

15           24.     The RAKE receiver of claim 20 further comprising a set of interference-scaling  
multipliers, wherein individual ones of the interference-scaling multipliers correspond to  
respective ones of the interference estimates, and wherein each interference-scaling multiplier  
is adapted to multiply the respective interference estimate with a particular interference scale  
value before the interference estimates are subtracted from the signals of interest.

20           25.     The RAKE receiver of claim 16 wherein the subtraction circuit comprises a set of  
individual differencing circuits, each adapted to subtract corresponding ones of the interference  
estimates from each of the signals of interest.

5           26.     The RAKE receiver of claim 25 further comprising a post-subtraction combining  
circuit for combining the signals of interest to form a combined signal of interest.

27.     A mobile terminal comprising:

10           a user interface adapted to allow a user to control the mobile terminal, and input local  
speech signals for transmission and hear remote speech signals recovered from  
received signals;

          a transmitter adapted to transmit the local speech signals to a base station via an RF  
transmit signal; and

15           a receiver adapted to recover the remote speech signals from a received composite  
signal; said receiver comprising:

20           at least one primary RAKE finger, each adapted to recover a signal of interest  
from a selected multipath signal within a received composite signal  
comprising a plurality of multipath signals by correlating the received  
composite signal with a PN code at a time offset corresponding to the  
selected multipath signal;

25           at least one interference estimator, each adapted to generate an interference  
estimate for a corresponding one of the at least one primary RAKE finger  
caused by a remaining one of the plurality of multipath signals with respect to  
the selected multipath signal from which the corresponding primary RAKE  
finger recovers the signal of interest; and

          a subtraction circuit for subtracting the interference estimates generated by the at  
least one interference estimator from the signals of interest recovered by the  
at least one primary RAKE finger.

5           28.     The mobile terminal of claim 27 wherein each one of the at least one interference estimators comprises:

          a plurality of secondary RAKE fingers, each adapted to generate an individual estimate of multipath interference in a first one of the plurality of multipath signals arising from a second one of the plurality of multipath signals by correlating the received  
10           composite signal with the PN code sequence at time offset corresponding to a selected one of the plurality of multipath signals shifted by a relative delay difference between the first and second multipath signals, wherein the selected multipath signal is not the second multipath signal;

          a first multiplier in each secondary RAKE finger adapted to multiply the individual  
15           estimate of multipath interference by a channel coefficient determined for the selected multipath signal on which the secondary RAKE finger operates;

          a combining circuit for combining the output from each secondary RAKE finger within the interference estimator to form a raw interference estimate;

          a second multiplier adapted to multiply the raw estimate by a power-scaling value to  
20           form a power-scaled raw estimate;

          a third multiplier adapted to multiply the power-scaled raw estimate by a channel-scaling value to form the interference estimate output by the interference estimator.

          29.     The mobile terminal of claim 28 wherein there are L primary RAKE fingers  
25           corresponding to L selected multipath signals, and up to (L – 1) interference estimators for each one of the L primary RAKE fingers, each of the up to (L – 1) interference estimators corresponding to a given one of the L primary RAKE fingers adapted to estimate the interference in the selected multipath signal corresponding to the given primary RAKE finger arising from a remaining one of the L selected multipath signals.

5           30.     The mobile terminal of claim 28 wherein the RAKE receiver is further adapted to  
determine the power-scaling value used in each of the at least one interference estimators  
based on propagation channel coefficients determined for relevant ones of the plurality of  
multipath signals.

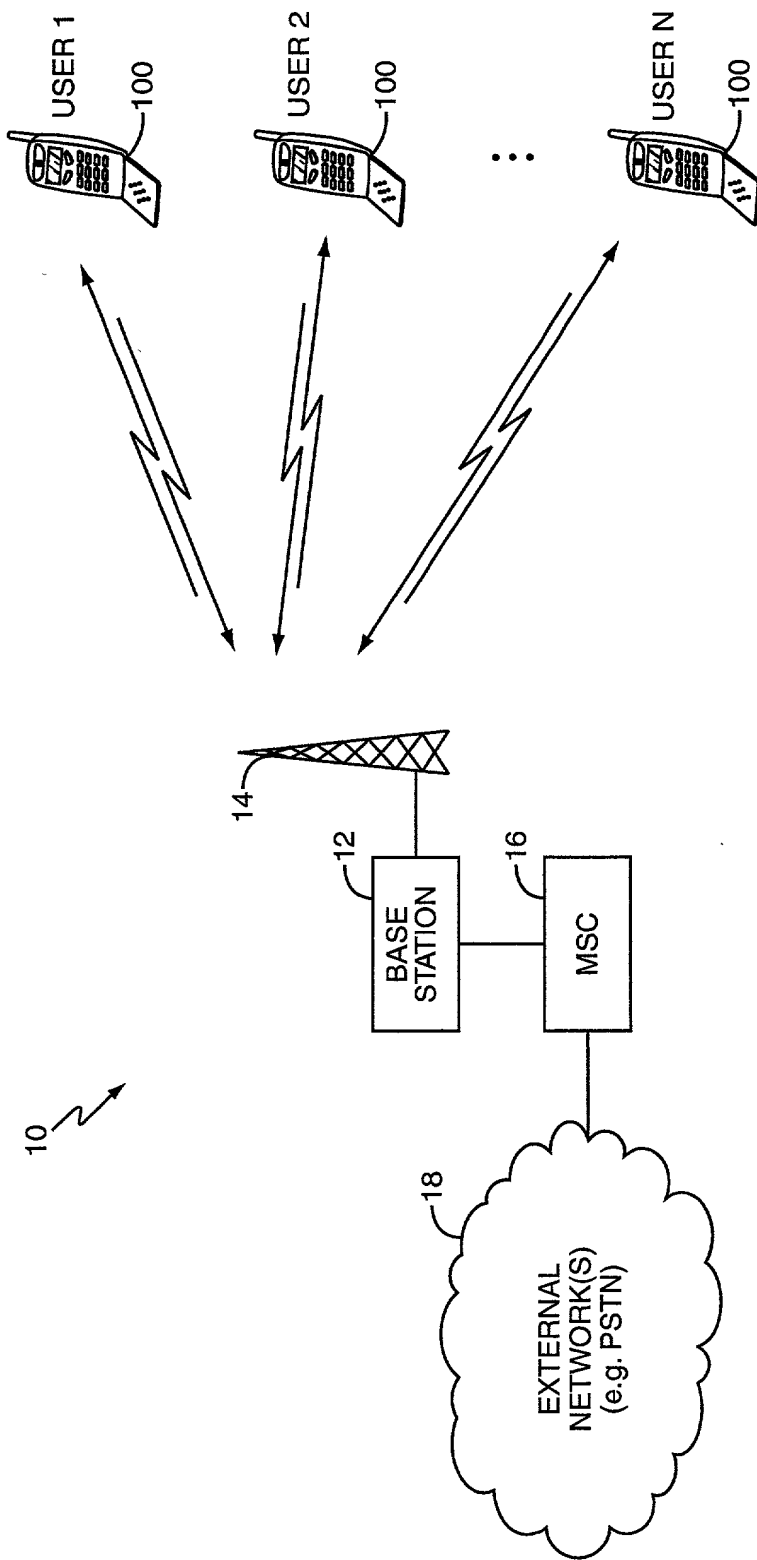
10           31.     The mobile terminal of claim 28 wherein the RAKE receiver is further adapted to  
determine the channel scaling value used in each of the at least one interference estimators  
based on propagation channel coefficients determined for the first and second multipath signals  
relevant to a given one of the at least one interference estimator.

15           32.     The mobile terminal of claim 28 further comprising a set of interference-scaling  
multipliers, wherein individual ones of the interference-scaling multipliers correspond to  
respective ones of the interference estimates, and wherein each interference-scaling multiplier  
is adapted to multiply the respective interference estimate with a particular interference scale  
value before the interference estimates are subtracted from the signals of interest.

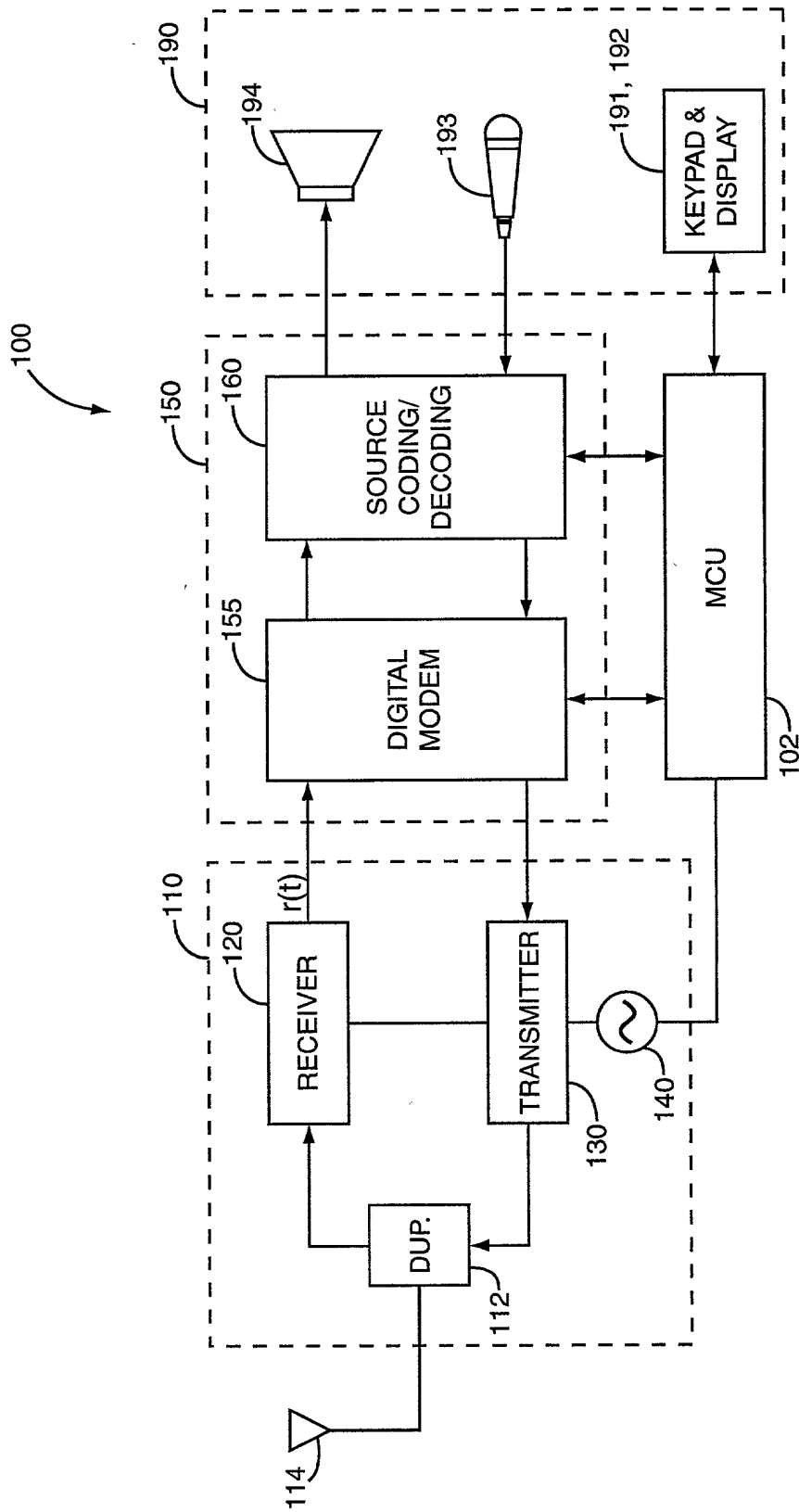
5

## ABSTRACT OF THE DISCLOSURE

A method and system reduce multipath signal interference in a CDMA receiver. The CDMA receiver comprising parallel first and second RAKE receivers receives a multipath signal. The first RAKE receiver includes a number of individual RAKE fingers, each operating with a defined finger delay matched to a propagation path delay. The output signal from each RAKE  
10 finger includes multipath interference. The second RAKE receiver includes a group of RAKE fingers corresponding to each RAKE finger in the first RAKE receiver. Each group of RAKE fingers is configured to produce an estimate of the multipath interference in the output signal generated by the corresponding RAKE finger in the first RAKE receiver. The estimated  
15 multipath interference signals are scaled, and then subtracted from the RAKE finger outputs from the first RAKE receiver to reduce multipath interference. Scaling coefficients are adjusted to ensure that such subtraction effectively reduces multipath interference.



**FIG. 1**



**FIG. 2**



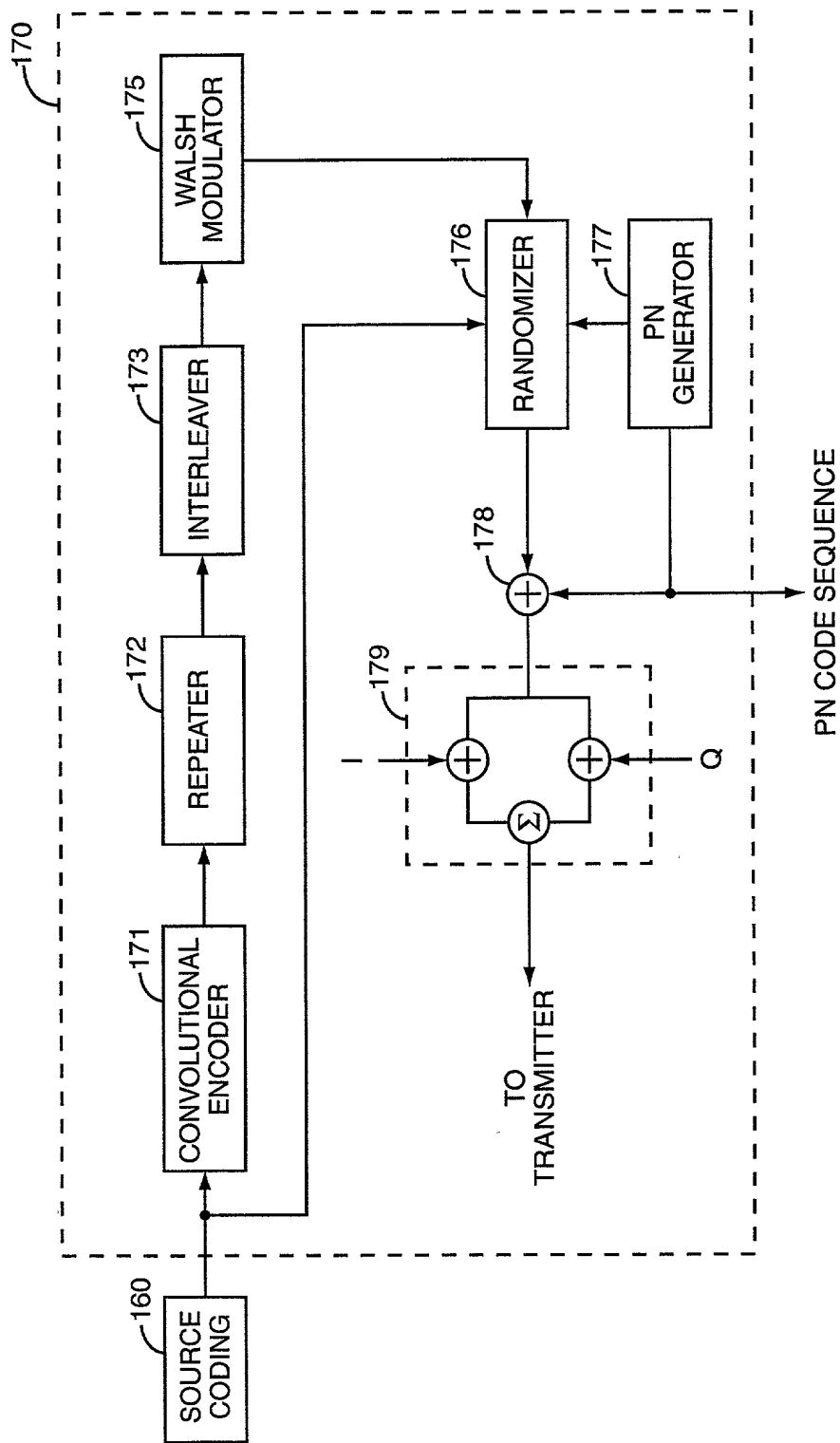


FIG. 3

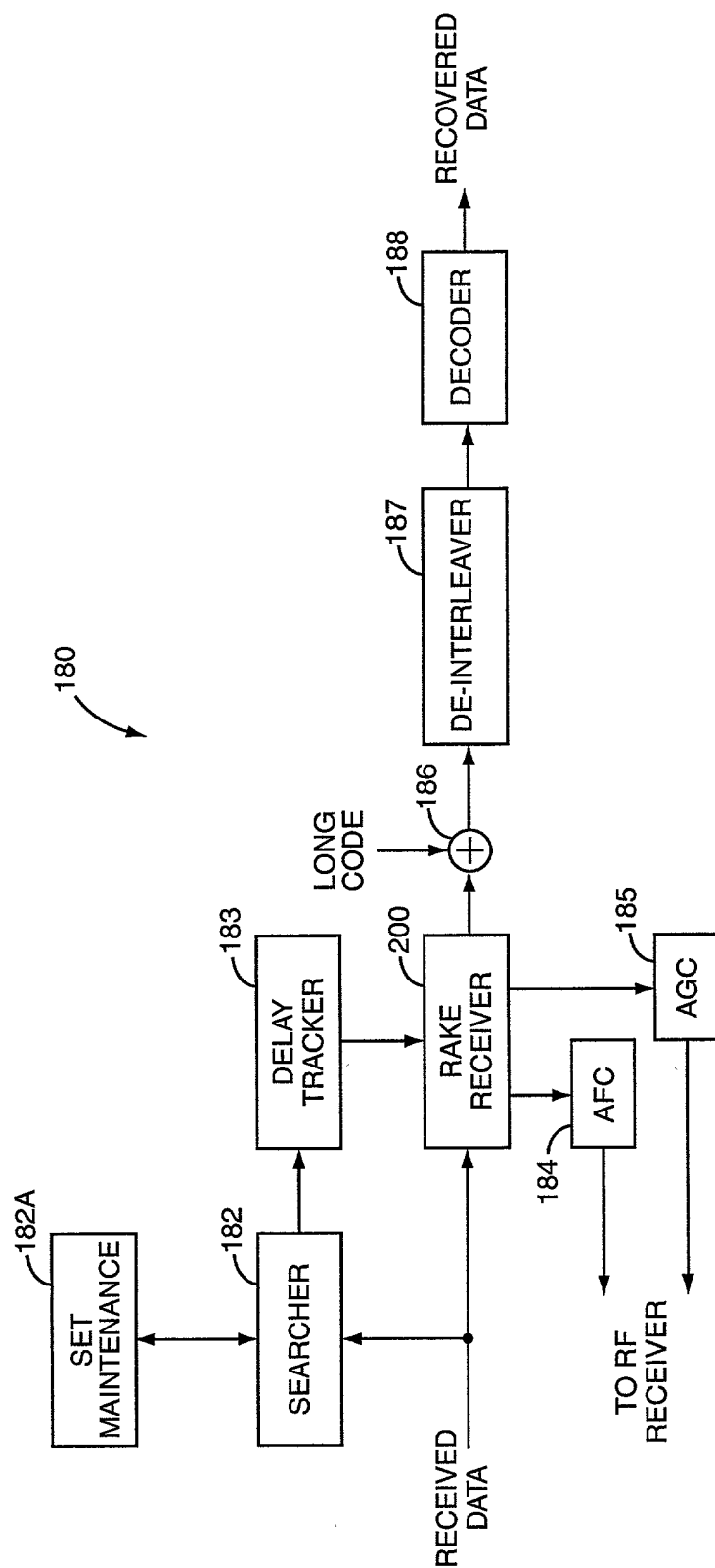


FIG. 4



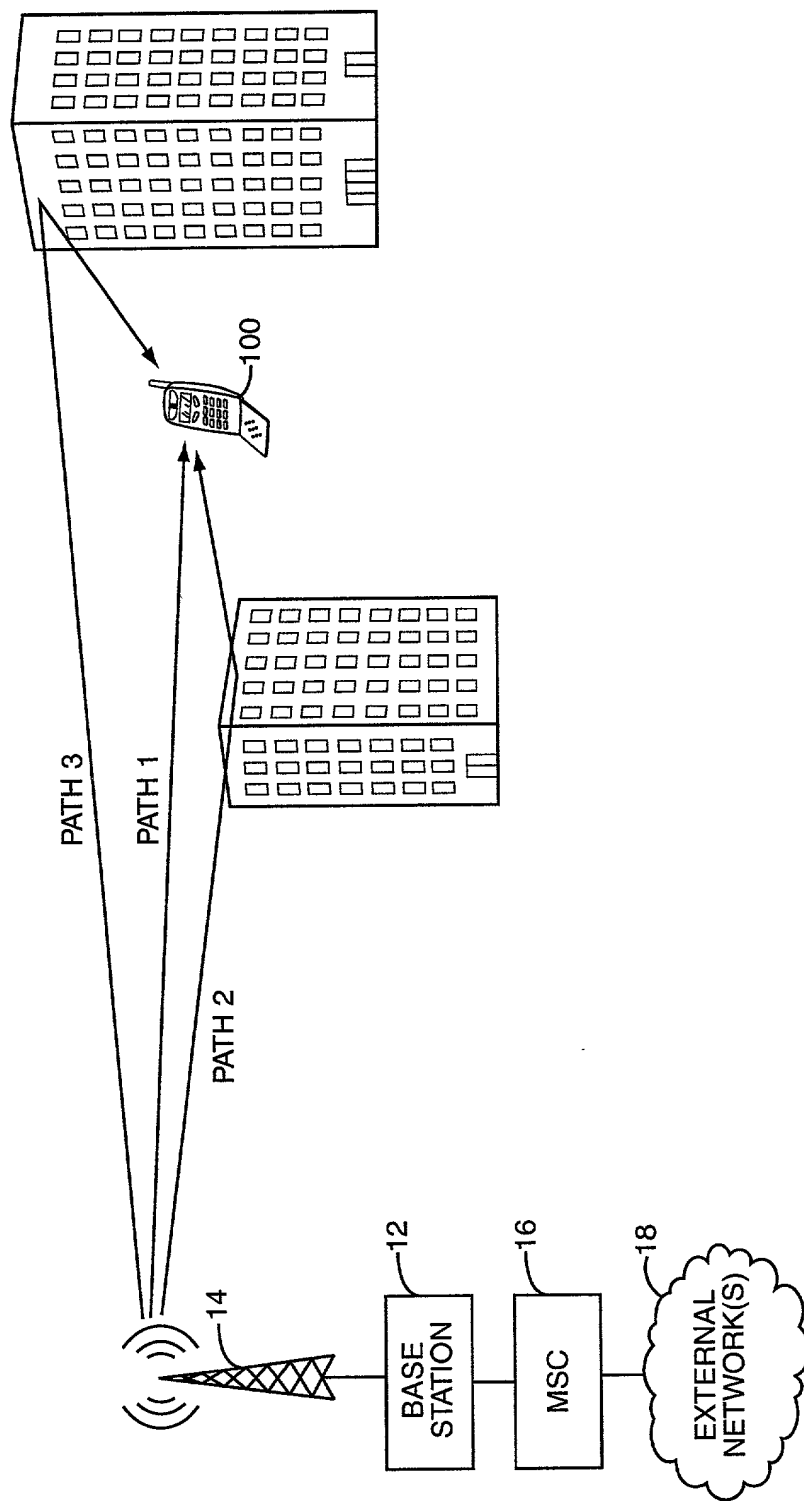
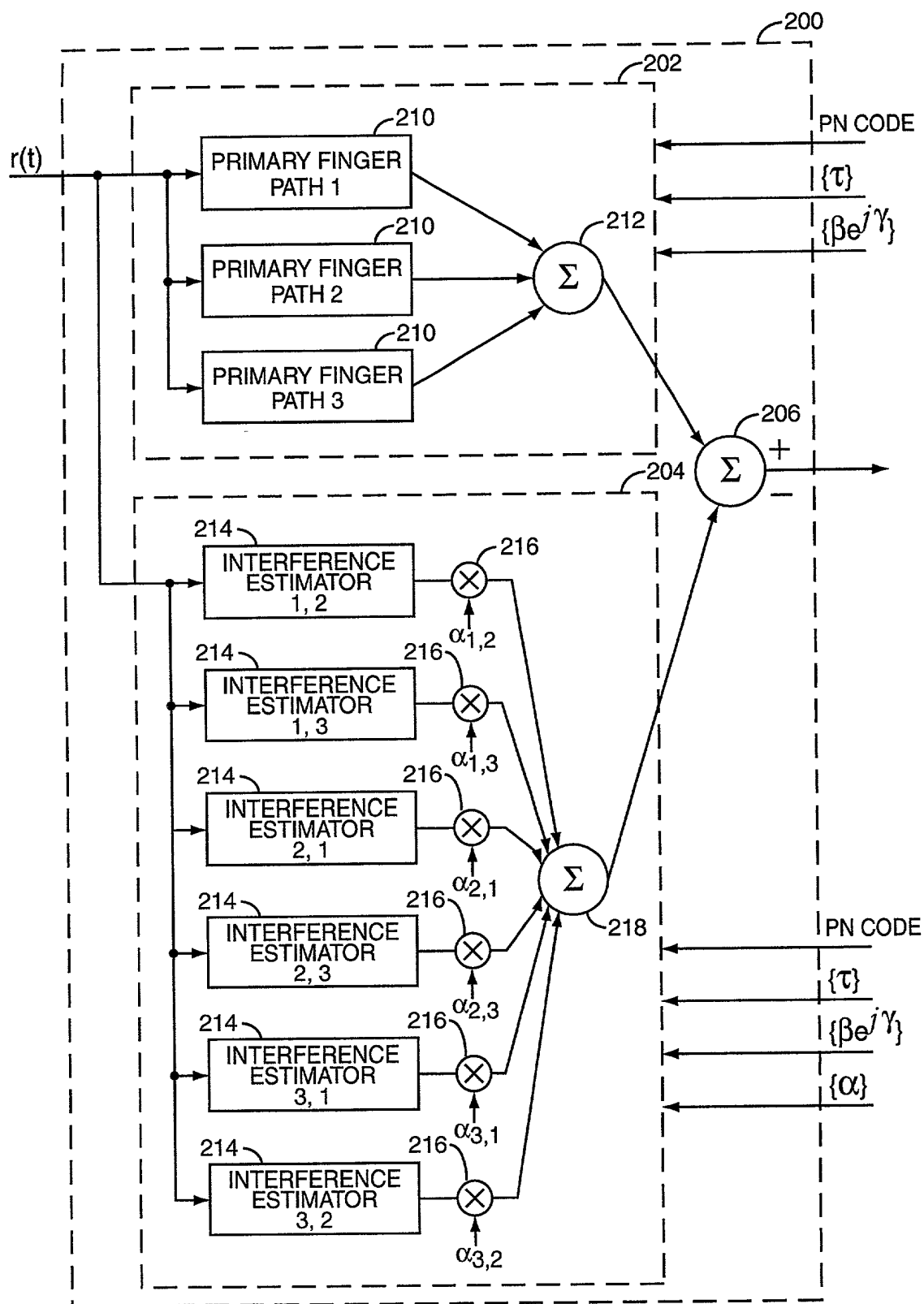


FIG. 6

[illegible]

**FIG. 7**

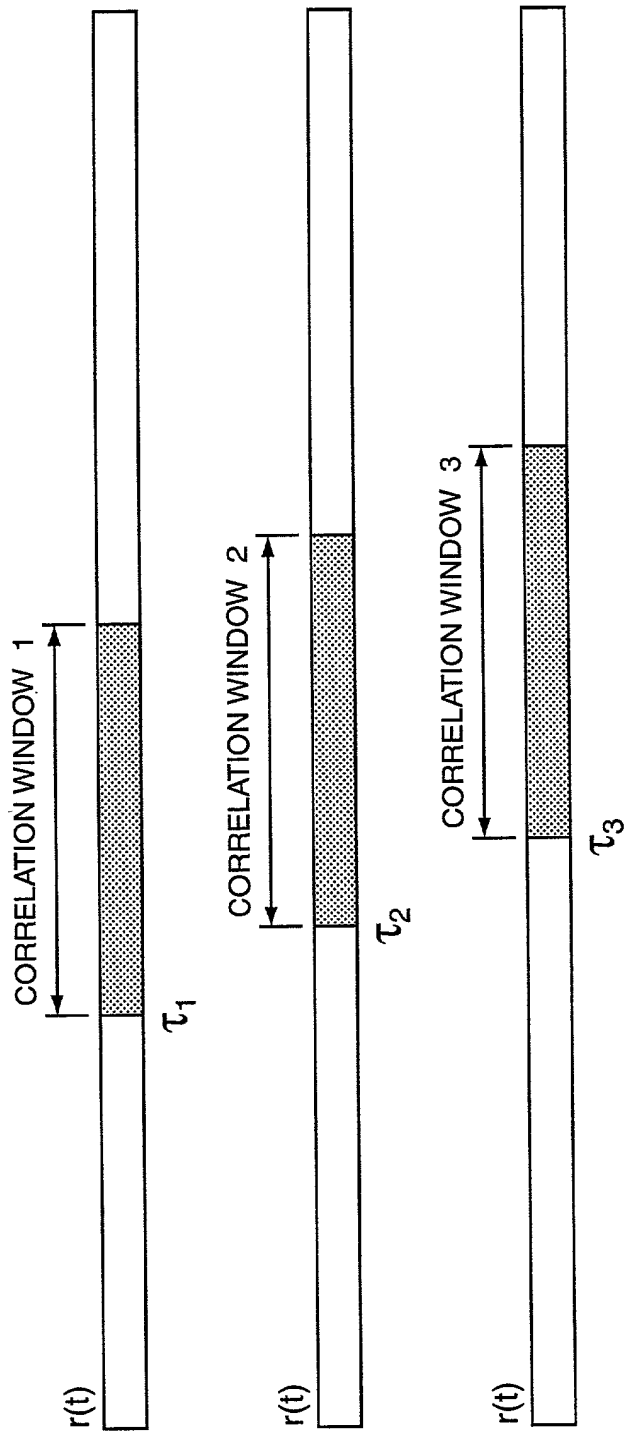


FIG. 8

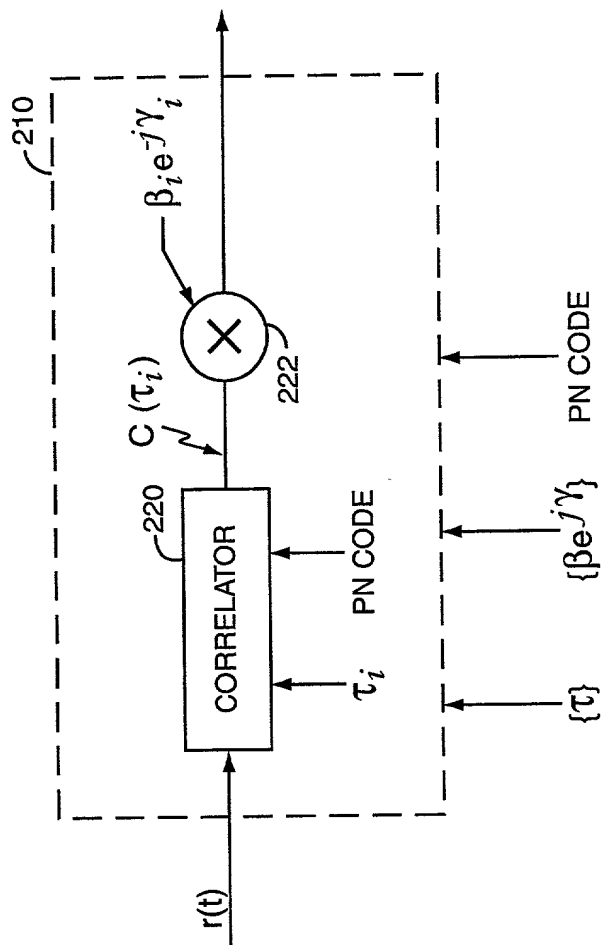


FIG. 9

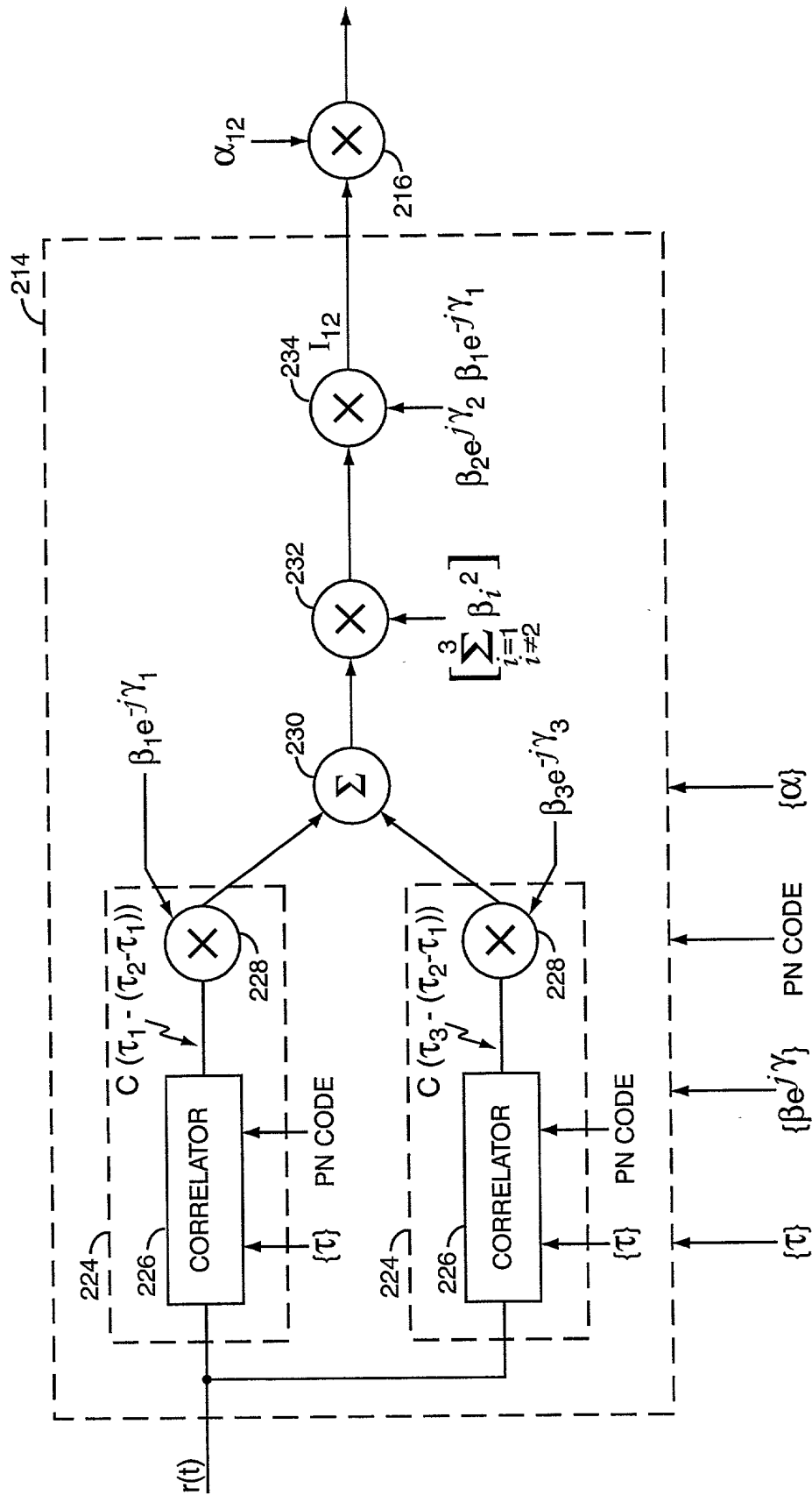


FIG. 10



## Declaration and Power of Attorney for Patent Application

As below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe that I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled MULTIPATH INTERFERENCE REDUCTION FOR A CDMA SYSTEM, the specification of which

☒ is attached hereto.

(Check one)

☐ was filed on \_\_\_\_\_ as  
Application Serial Number \_\_\_\_\_  
and was amended on \_\_\_\_\_  
(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose to the U.S. Patent and Trademark Office all information known to me which is material to patentability (as defined in C.F.R. §1.56) in connection with the examination of this application.

I hereby claim foreign benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

NONE (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> YES	<input type="checkbox"/> NO
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	<input type="checkbox"/> YES	<input type="checkbox"/> NO

## Declaration and Power of Attorney for Patent Application

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

NONE

(Application Serial No.)

(Filing Date)

(Status: Patented/Pending/Abandoned)

(Application Serial No.)

(Filing Date)

(Status: Patented/Pending/Abandoned)

**Power of Attorney:** As a named inventor, I hereby appoint the following agents/attorneys to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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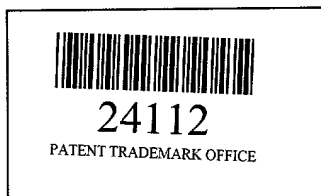
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**Declaration and Power of Attorney for Patent Application**

And I also hereby appoint the Attorneys and Patent Agents of **Coats & Bennett, P.L.L.C.**, as identified by **Customer Number 24112** in the records of the United States Patent and Trademark Office and as updated from time to time, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.



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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

**SOLE OR FIRST INVENTOR:**

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